Figure 56—Accumulations of logs provide cover for small mammals but may impede movement by deer and elk.

Figure 57—Prey captured by great gray owls is often associated with down woody material.

Figure 58—Rubber boas (*Charina bottae*), other reptiles, and amphibians may burrow into decayed logs.

Figure 59—Hollow logs are used by martens, black bears, and smaller mammals for den sites and shelter.

Figure 60—Black bears forage extensively on carpenter ants and beetle larvae in logs during late summer and fall.

Figure 61—Slash piles provide cover for wildlife.

years, thus diminishing their wildlife habitat values even if such logs are well distributed and of large size (Maser and others 1979). The works of Maser and Trappe (1984) and Lofroth (in press) are excellent sources for more information on the dead wood cycle and terrestrial and aquatic life processes in logs.

The Log Resource

Size, species, and-number *of* fogs-These factors may be the most basic ones in describing the log resource in terms of its use by wildlife. Little information exists on the significant descriptive features for log resources. Appendix B provides a sample data form for inventories of the down log resource. Even determining the species of a decayed down log can be challenging, especially when some or all of the branches, cones, and bark are missing. Parks and others (in press) have prepared a field guide as an aid to identifying species of snags and logs of the interior Columbia River basin.

Bull and Holthausen (1993) found that in 38 percent of their observations of foraging pileated woodpeckers, the birds used Douglas-fir and western larch logs in mixed-conifer stands. Moreover, these birds favored logs that were 15 inches or greater in large-end diameter and in advanced stages of decomposition. A companion study to determine log characteristics that influenced the ant prey of woodpeckers showed the same pattern in occupation of logs by carpenter ants (Torgersen and Bull 1995), the primary prey of pileated woodpeckers (Beckwith and Bull 1985).

Determining whether wildlife use of particular logs is related to the species or to the size of the log is difficult. In studies by Torgersen and Bull (1995) lodgepole pine, which had the smallest mean diameters of logs, rarely supported populations of the wood-dwelling ants used as food by pileated woodpeckers. Conversely, western larch, Douglas-fir, and grand fir, which had the largest mean diameters, commonly supported these ant colonies. More specifically, the study determined that western larch logs were preferred for pileated woodpecker foraging and for colonization by wood-dwelling ants. Larch also had the greatest mean large-end diameters (13 inches) and represented about 14 percent of the logs, but their proportional use was far greater. Douglas-fir, grand fir, and ponderosa pine logs had mean diameters of about 12 inches and represented about 58 percent of the logs in the mixed-conifer study stands. Their use by ants and foraging woodpeckers approximated their representation in the total log resource. Lodgepole pine logs, however, which averaged only 9 inches in large-end diameter and represented 18 percent of the logs, were used much less than their representation among all logs. From the standpoint of ant colonization and woodpecker foraging, log size may be more important than species (Bull and Holthausen 1993, Torgersen and Bull 1995).

Another characteristic describing log resources is the length of logs. This is expressed as mean length of logs or total linear length of logs per acre. Data on lengths of logs in late- and old-structure mixed-conifer stands in northeastern Oregon indicate that for all species 6 inches or larger in large-end diameter, logs averaged 34 feet. Mean length for logs 15 inches or larger in large-end diameter was 47 feet. Among species for all diameter classes, ponderosa pine averaged the shortest (23 feet) and lodgepole pine the longest (45 feet). In these same stands, overall length of logs 6 inches or greater in large-end diameter was 2,064 to 4,928 linear feet per acre. Of this total, there were 175 to 602 linear feet of logs per acre 12 inches or greater in diameter. Logs in this latter size range are the stated size of logs for wildlife habitat in the Regional Forester's Decision Notice to adopt Eastside Forest Plan Amendment No. 2 (U.S. Department of Agriculture 1995). For mixed-conifer stands east of the Cascade Range, this Plan Amendment stipulates 15 to 20 logs per acre, 6 or more feet long, with a total linear length of 100 to 140 feet of logs 12 inches or greater in small-end diameter. The above limited data suggest that the target linear length stipulated in the Plan Amendment is considerably less than observed in 15 study stands (Torgersen 1997).

Studies by Bull and Holthausen (1993) and Torgersen and Bull (1995) reported about 117 logs per acre in 12 late-structure mixed-conifer stands. In these studies, all logs that had at least 6 feet of their length in the 0.1 -acre plots were tallied. This criterion resulted in a misleading density of logs per acre. Further interpretation of only logs whose mid lengths fell within the 0.l-acre plots indicated that the actual number of logs per acre was 24 percent less than the total number of logs entering the plots. Thus, an average number of 88.8 logs per acre (standard error [SE] = 6.9) more accurately describes the true density of logs in the 12 home ranges of pileated woodpeckers in that study. Using the mean length of 34 feet per log translates to 3,026 linear feet of logs per acre in these home ranges.

Additional research in six stands of old-growth mixed conifers in northeastern Oregon showed an average of 92.9 logs per acre (SE = 11.9). Inventories in four stands of late-seral mixed conifers in northeastern Oregon showed an average of 88.5 logs per acre (SE = 14.5). The similarity in log densities among 27 widely distributed stands in four counties in northeastern Oregon suggest that log resources may be quite similar, about 90 logs per acre, in late- and old-seral stands of mixed conifers there (Torgersen 1996).

Inventories of logs in four ponderosa pine stands in northeastern Oregon that were selectively logged for the largest trees about 40 years ago show an average density of 45.5 logs per acre (SE = 8.3) (Torgersen 1996).

Studies conducted in coastal Douglas-fir forests west of the Cascade Range have used percentage of ground covered by logs as a feature against which to relate abundance of some small vertebrates and their food, particularly hypogeous fungi (truffles and trufflelike fungi) (Amaranthus and others 1994, Carey and Johnson 1995). Percentage of ground covered by logs has not been a habitat feature used to relate to wildlife in the interior Columbia River basin. We suggest that this feature may be a good one to include in assessments of down wood resources. Percentage of ground covered by logs can be calculated from the data we propose be collected in the log sampling form in appendix B.

***Log structural classes*-Logs** may be in various stages of decomposition, from sound, newly dead trees, to logs that have deteriorated to the point of having nearly blended into the forest floor. Exterior appearance and interior structure differ among logs of various ages just as they do in living trees and snags. Maser and others (1979) classified logs by exterior appearance into log decomposition classes. In contrast, the physical properties of internal structure and wood soundness are here called "wood condition"--the extent to which the wood has become soft, friable, spongy, or pitted as a result of attack by decay-causing organisms and channeling by invertebrates (Torgersen and Bull 1995).

The five log decomposition classes of Maser and others (1979) describe the physical appearance of deteriorating down trees. They characterized the classes by the presence or absence of bark and small twigs, the texture and color of the wood, the shape or amount of decomposition of the log, and the amount of contact of the log with the forest floor.

Unless evidence suggests otherwise, we suggest that three log decomposition classes are sufficient to classify the extent of degradation of fallen trees relative to most wildlife use. Thus we propose three log structural classes (figs. 62 and 63): log decomposition classes 1 and 2 of Maser and others (1979) are incorporated into log structural class 1, decomposition class 3 becomes structural class 2, and decomposition classes 4 and 5 become structural class 3.

Wood ***condition*-Any** examination of logs will show a range of external and internal wood conditions. Some logs may be almost uniformly sound or uniformly rotten; others may have sound heartwood but sapwood that has become crumbly as a result of colonization by fungi, beetle larvae, or ants. In northeastern Oregon sites, Torgersen and Bull (1995) used three wood condition classes (sound, moderately decayed, and advanced decay) to describe logs. Discriminant analysis suggested that this variable was only rarely related to either signs of foraging by pileated woodpeckers or presence of ants. Carpenter ants, the dominant prey of pileated woodpeckers, tended to be associated with sound wood, and more specifically with sound, large-diameter western larch.

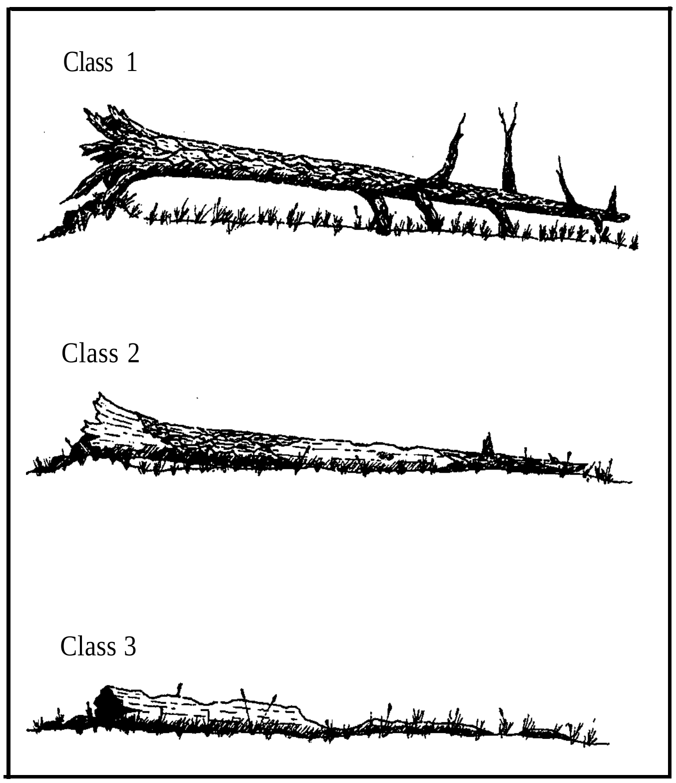


Figure 62-Three structural classes of logs.

Assessing wood condition is highly subjective but may be estimated by using a hatchet to chop into the log at intervals along its length. The butt end of a log may be much softer than portions toward the small-diameter end. Because wood conditions vary in a log and because the sampling procedure is subjective, the relevance of wood condition to wildlife use is unclear. Nonetheless, we have included this variable on the sample data form for characterizing down log resources (appendix B). The decision to record wood condition is left to the user.

Hollow logs-Because of the exceptional values of this structural component to wildlife, we propose that this feature be specifically recorded in describing the character of log resources (appendix B).

***Inventory** of* logs-Much study has been devoted to portraying amounts of down material as fire fuels (Fischer 1981a, 1981b, 1981c; Koski and Fischer 1979; Maxwell and Ward 1976, 1980). The breakdown into tonnages or volumes and the photo series for classifying forest residues, however, are of limited utility to biologists who want to describe log resources in ways that are relevant to use by wildlife. Management agencies already need estimates of log resources in stands to assure compliance with stated management goals in planning documents.

A survey of logs along transects and in fixed-size plots can be used to estimate numbers of logs per acre, species composition, and proportion of logs by diameter-class in selected stands (appendix C). The line transect method for assessing log resources was adapted from sampling techniques used to determine volume and tonnage of down woody fuels (Brown 1974, Brown and others 1982). A modification of this method uses 18 clusters of three 75-foot transects to characterize log populations in stands up to about 30 acres (Ottmar 1996). The fixed-plot method uses 18-20 circular or square 1/40th-acre plots to determine log populations in a 30-acre stand. See appendix C for detailed descriptions of these sampling schemes.

Information on numbers, sizes, and other characteristics of logs that produce suitable habitat for wildlife is scanty. The information given here is based on our research, which is limited to mixed-conifer stands in known pileated woodpecker home ranges (Bull and Holthausen 1993, Torgersen and Bull 1995) or data from other selected stands in the Blue Mountains of northeastern Oregon (Torgersen 1996). The management options offered above are based on preliminary information, and we anticipate that management will adopt different options as new information becomes available.

Review

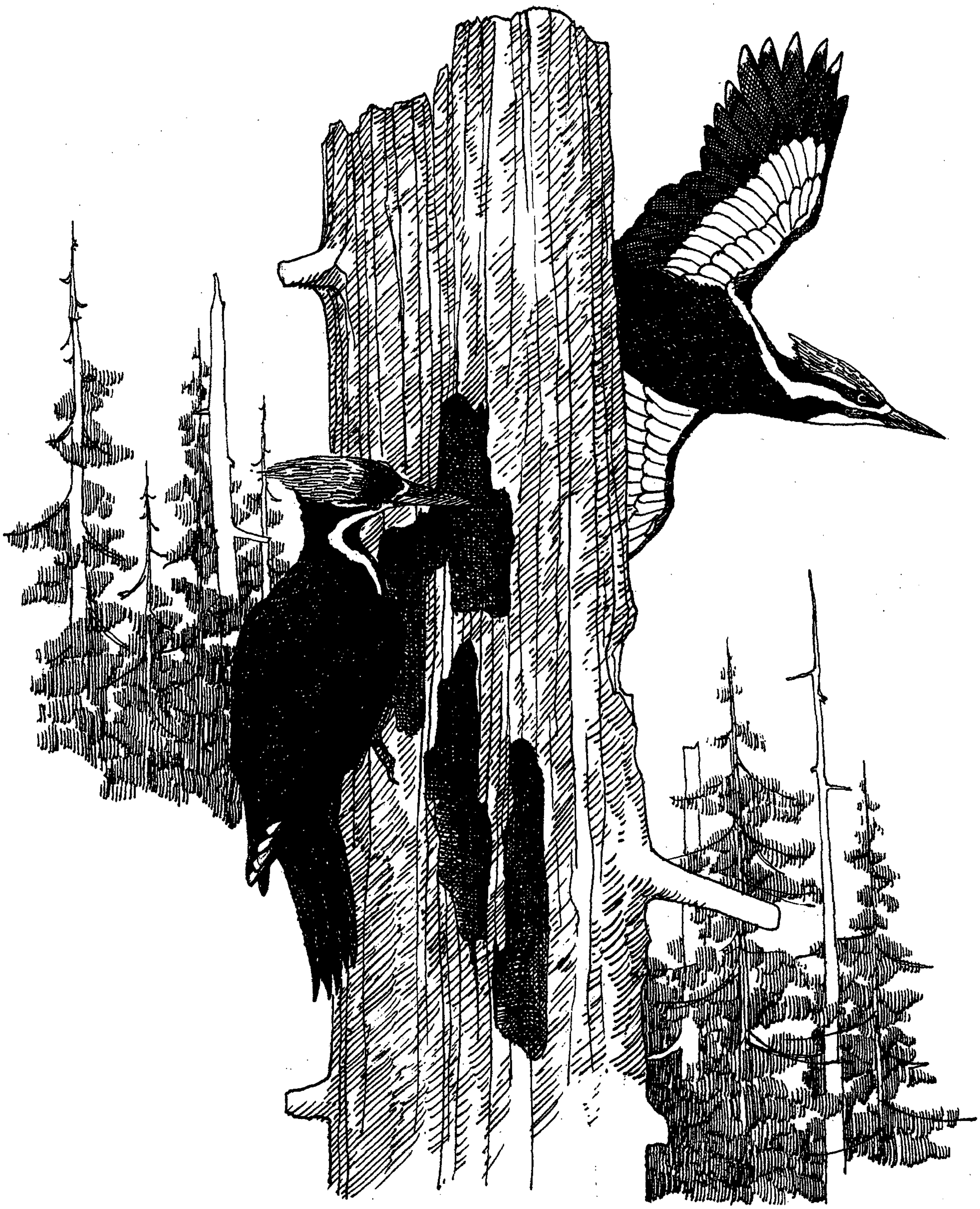
- Size, species, and number of logs per acre are fundamental descriptors of the suitability of log resources for wildlife.
- Logs 15 inches or greater in large-end diameter are particularly important for species such as pileated woodpeckers.
- In mixed-conifer stands, logs of western larch, Douglas-fir, and grand fir were favored for foraging by pileated woodpeckers in northeastern Oregon.
- Late- and old-seral stands of mixed conifers have about 90 logs per acre in northeastern Oregon.
- Logs averaged 34 feet long in mixed-conifer stands in northeastern Oregon, but logs should be as long as possible to offer the greatest range in diameters.
- Hollow logs of any species and size class are important structural components to favor.

Class 1

Class 2

Class 3

Figure 63—Three structural classes of logs.



CONCLUSIONS

This document presents new information on the retention and selection of trees and logs most valuable to wildlife. This new information may be useful in the forest planning process. As additional information becomes available, agencies can incorporate it into their management guidelines.

Current direction for providing wildlife habitat on public forest lands does not reflect this new information. Since the publication of Thomas and others (1979), new research suggests that to fully meet the needs of wildlife, additional snags and habitat are required for foraging, denning, nesting, and roosting. Although we do not suggest specific numbers of snags to retain by forest type, two recent studies indicate that viable woodpecker populations occurred in areas with about four snags per acre (Bull and Holthausen 1993, Dixon 1995).

We suggest that the next step in snag management should involve creating a model that incorporates the new information on woodpecker foraging substrates (live trees, snags, and logs), home range sizes, number and characteristics of roost trees, multiple occupancy of snags, and needs for other habitat structures. Once this information is incorporated, the model may suggest changes to guidelines that specify numbers of snags and other habitat features by forest type and geographic area. Additional information on fall rates of snags, foraging needs of black-backed and three-toed woodpeckers, relation of the density of woodpeckers to that of secondary cavity nesters, and relation of snag density to woodpecker density would greatly improve the model.

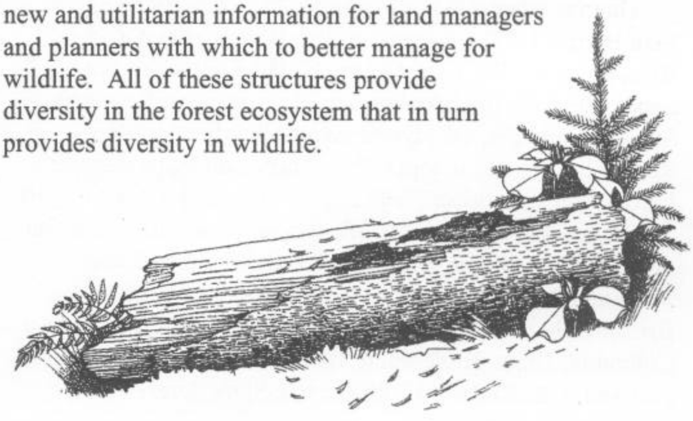
Although hollow trees provide benefits to many wildlife species, no framework regarding their management exists. Additional research is needed to clarify how and when heart-rot decay is initiated, and how long hollow trees persist. Management actions that foster the development and retention of hollow trees need to be developed.

In spite of the value of dwarf mistletoe brooms to wildlife, many managers are still reluctant to retain such structures in stands. With creative management, selected areas can be identified in which to retain trees with dwarf mistletoe brooms but still minimize the risk of spread of dwarf mistletoe to the rest of the stand. Information presented here suggests that retaining trees with brooms caused by broom rusts or Elytroderma offers little risk of tree mortality within a stand.

We are just beginning to recognize the importance of logs in wildlife management. Inventories in 22 areas in northeastern Oregon showed that late- and old-seral stands of mixed conifers contained about 90 logs per acre. These inventories raise questions regarding current guidelines that call for only 6 to 20 logs per acre. Logs are important not just for wildlife but for maintenance of nutrient recycling, water economy, and structural properties for plant growth and soil development that logs provide.

For any management plan to be effective, a reasonable estimate of existing conditions is essential. To obtain this information, inventories of snags, logs, hollow trees, and trees with brooms can be done by using techniques recommended in this text. For down logs, the minimum information needed for wildlife purposes are large-end diameters of logs, lengths, and numbers per acre. Fuel inventories do not provide this information. Once existing conditions are known, management direction can dictate the number and type of structures to retain and the number that can be removed without jeopardizing wildlife objectives.

We hope that this document will provide some new and utilitarian information for land managers and planners with which to better manage for wildlife. All of these structures provide diversity in the forest ecosystem that in turn provides diversity in wildlife.



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MONITORING CREATED WILDLIFE TREES

Forest or Location: ______________________________ Monitoring Crew: ____________________ Stand or Area: ___
______________________________ Date of Remeasurement: ______________
Contact Person: ______________________________
Date of Treatment: ______________________________

TREATMENT DATA | REMEASUREMENT DATA

Tree #	Tree Sp.	DBH (in.)	Pre-Trt. Ht. (ft.)	Treat-ment	Ht. of Trt. (ft.)	GPS Points	Defects/Comments	Yrs. Since Trt.	Tree Cond.	Tree Ht. (ft.).	% Live Crown	Forage Use	Nest Use	Comments

Tree Species
1 = Ponderosa pine
2 = W. white pine
3 = Douglas-fir
4 = Grand/White fir
5 = W. larch
6 = Lodgepole pine
7 = W. hemlock
8 = W. red cedar
9 = Aspen
10 = Cottonwood
11 = Birch
12 = Other

Treatments
1 = Dynamite top
2 = Sawn top
3 = Inoculate
.1 Fungus
.2 Fungus
4 = Girdle
5 = Silvicide
6 = Other

Tree Condition
1 = Live
2 = Dead
3 = Broken
4 = Down

Wildlife Use
0 = No
1 = Yes

Comments
(describe wildlife use; nests, conks, defects, etc.)

Appendix B Data Form for Inventorying Down Logs

Log Inventory

Forest or Location: ______________________________

Monitoring Crew: ______________________________

Stand or Area: ______________________________

Date: ______________________ Contact Person: ______________________

Stand History (burned, harvested, firewood cutting, insect/disease activity): ______________________________

____

____

____

Transect or Plot #	Log #	Log Class	Log Species	Log Structural Code	Measurements			Hollow Log	Wildlife Use		Comments
					Large Diameter (in.)	Small Diameter (in.)	Length (ft.)				

Log Glass

1=Natural log
2=Cut log
3=Natural log
4=Cut Stump

Log Species

1=Ponderosa pine
2=W. white pine
3=Douglas-fir
4=Grand/White fir
5=W. larch
6=Lodgepole pine
7=W. hemlock
8=W. red cedar
9=Aspen
10=Cottonwood
11=Birch
12=Other

Log Structural Code

1-3; PNW GTR 391, Figure 56 & 57

or

1-5; Maser and others (1979)

[circle one]

Measurements

*Large diameter of log is taken just above butt-swell at "stump" height.

* Use "length" column to record height of stump.

* Use "large diameter" column to record stump diameter.

Hollow Log

0=No
1=Yes

Wildlife Use

0=No excavations 1.0" or larger in diameter
1=Woodpecker foraging (sapwood)
2=Woodpecker Foraging (heartwood)
3=Bear foraging
4=Bear den
5=Squirrel cache
6=Other

Appendix C

Methods for Log Inventories

Line-transect method --The line-transect method is especially well adapted to sampling large areas or stands with varying topography and plant communities. For sample areas up to 30 acres, 18 plots each containing three 75foot-long transects (fig. 64A) will characterize log density within about 20 percent of the mean density of logs per acre. Such an array would contain a total of 4,500 linear feet of transect (three 75-foot transects by 18 plots). Transects totalling 4,500 to 6,000 linear feet can be used to characterize a 30-acre stand (Ottmar 1996). Larger areas might use proportionately longer totals for linear feet of transect.

Depending on the number of plots chosen, they may be placed at 66- to 198-foot intervals (1 to 3 chains) or more along a course in the sample area. The azimuths of the lines composing the course are chosen to ensure that plot centers fall at least one and one-half tree lengths within the margins of the stand. At each plot center, three radiating transects, 120° apart, are established. For each plot, the azimuth of the first transect is selected from a random-number table or wristwatch (multiply seconds by 6 to get azimuth of first transect). Each succeeding transect is 120° from the preceding one. The 75-foot transects are measured and marked by with a measuring tape. Crossing of transects from adjacent plots can be minimized by increasing the spacing between plot centers to more than 112 feet (2 chains).

An alternative method for laying out transects for log inventories is described in the Forest Service manual for Current Vegetation Survey (CVS). The layout for CVS incorporates five 51. l-foot radii of subplots within the sample unit design (U.S. Department of Agriculture 1997).

All logs with a large-end diameter of 6 or more inches are tallied, without regard to what portion of the log is intercepted by the transect. A break-point diameter greater than the above 6-inch limit may be chosen depending on sizes of logs present, or specific purpose of the log inventory. This streamlines the sampling but will yield less information relevant to wildlife habitat.

Minimum data needed for each intercepted log are large-end diameter just beyond the butt swell, small-end diameter, and total length of log in feet. These measurements will permit computation of per-acre values for number of logs, volume, percentage of ground covered by logs, and linear feet of logs. One method for computing log volume is to use Smalian's formula (Wenger 1984) and to convert to cunits (CCFs). Other useful variables that may be recorded for each log are shown in the log inventory form (appendix B).

Number of logs per acre may be calculated by substituting total transect length and log lengths in equation 1 adapted from De Vries (1973) and Pickford and Hazard (1978), and applying constants to obtain pieces per acre where lengths of transects and logs are in feet:

$$N = ((43{,}560 \times 3.1416) / (2 \times L)) \times (l/a_1 + l/a_2, ... + l/a_3), \quad (1)$$

where

N = number of logs per acre,
L = length of transect in feet, and
a = length of each log in feet.

Fixed-area plots-Circular or square plots of 1/40th-acre are a manageable size to sample. Areas of 20 to 30 acres can be characterized with 10 to 18 plots. Plots are established along sampling courses as described above for line transects. At each sample point, a random azimuth of 75-foot length is selected as above. The sample plot is laid out at the end of the transect. The end of the transect may be the center of a circular plot or a corner of a square plot (fig. 64B). Each log whose midlength falls within the boundaries of the plot is tallied. Log parameters as described for the line-transect method are recorded. Log density is calculated based on the 1/40th-acre plot size, that is:

$$\text{Logs per acre} = \text{logs per plot} \times 40. \quad (2)$$

With both line-transect and fixed-area plots, measures of variance may be obtained by using densities of logs for individual clusters of transects or plots to obtain SE's for mean densities over the sample area. Because larger logs generally provide better wildlife habitat, densities of logs by selected large-end-diameter classes and lengths may be more meaningful than density of logs per acre alone.

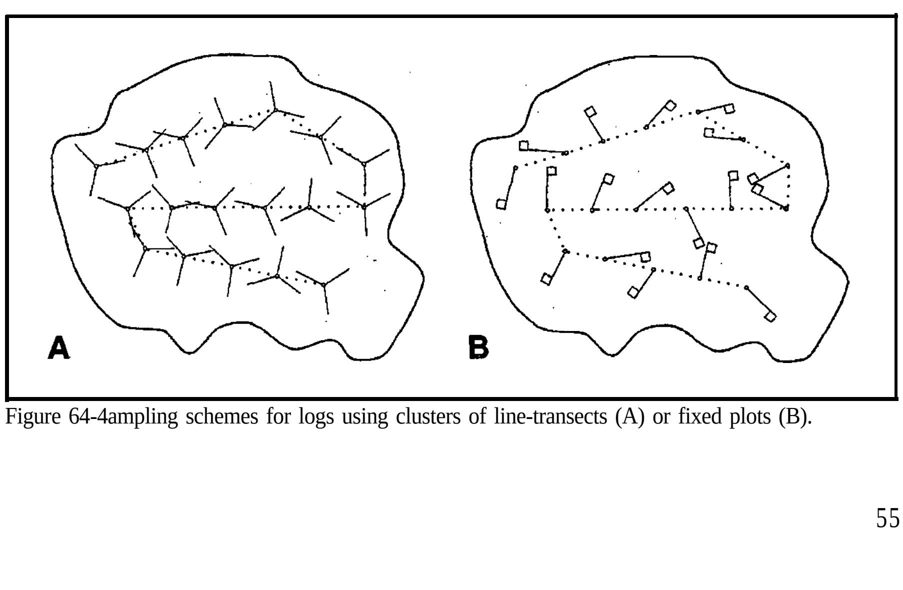

Figure 64-4ampling schemes for logs using clusters of line-transects (A) or fixed plots (B).

Bull, Evelyn L.; Parks, Catherine G.; Torgersen, Torolf R. 1997. Trees and logs important to wildlife in the interior Columbia River basin. Gen. Tech. Rep. PNW-GTR-391. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 55 p.

This publication provides qualitative and quantitative information on five distinct structures: living trees with decayed parts, trees with hollow chambers, trees with brooms, dead trees, and logs. Information is provided on the value of these structures to wildlife, the decay or infection processes involved in the formation of these structures, and the principles to consider for selecting the best structures to retain.

Keywords: Broom rust, cavity nesters, decay fungi, dwarf mistletoe, Elytroderma, forest management, habitat monitoring, hollow trees, interior Columbia River basin, logs, old-growth forests, snags, wildlife, wood decay.

Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, Oregon 97208-3890

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Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
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